

MULTI-MOK MODULATION/DEMODULATION TRANSMISSION PROCESS,
CORRESPONDING TRANSMITTER AND RECEIVER

DESCRIPTION

FIELD OF THE INVENTION

The present invention relates to a multi-MOK modulation/demodulation transmission process, and the corresponding transmitter and receiver.

5 The invention is generally applied in digital applications and more particularly in wireless local area networks WLAN, wireless local loops WLL, mobile telephone communications, home automation and remote collection, communications in transportation, cabled
10 television and multimedia services on cabled networks, etc.

STATE OF THE RELATED ART

The invention is based on the spectral spread
15 technique. It is known that this technique consists of the modulation of a digital symbol to be transmitted by a pseudo-random sequence known by the user. Each sequence is composed of N items called "chips", the duration of which is one Nth of the duration of a
20 symbol. This results in a signal with a spectrum spread over a range N times broader than that of the original signal. At reception, the demodulation consists of correlating the signal received with the sequence used at transmission to obtain the initial symbol.

25 This technique offers numerous advantages:

- discretion, since, as the power of the transmitted signal is constant and distributed over an N times broader band, its spectral power density is reduced by a factor N;

5 - immunity to voluntary or parasitic narrow band transmissions, the correlation operation carried out at the receiver resulting in the spectral spread of these transmissions;

10 - difficult interception (for usual signal to noise ratios), since the demodulation requires the knowledge of the sequence used at transmission;

- resistance to multiple paths which, under some conditions, induce selective frequency fading and, therefore, only affect the transmitted signal
15 partially;

- possibility of a code division multiple access or CDMA: several direct sequence spectral spread links can share the same frequency band using orthogonal spread codes.

20 However, this technique has one disadvantage: its low spectral efficiency. This term refers to the data bit rate and the width of the band occupied. If each data symbol contains m bits, the data bit rate is equal to m times the symbol rate, or mDs. The occupied band
25 is equal to double the chip frequency, i.e. 2N times the symbol rate, or 2NDs. Therefore, this gives a spectral density equal to the ratio $\frac{mDs}{2NDs}$, or $\frac{m}{2N}$.

It would be possible to consider increasing the spectral efficiency by decreasing N, but this would
30 affect the inherent qualities of the spread and, in particular, would have a detrimental effect on the

immunity of transmissions. It would also be possible to consider increasing the symbol rate, but interference between symbols would be worsened.

Another solution would consist of increasing m , the number of data bits per symbol, which would result in the use of complex, "higher order" modulations. Indeed, the present invention uses this method. Therefore, it is possible to summarise what these modulations consist of, essentially two of said modulations, i.e. PSK or "Phase Shift Keying" modulation, which is a phase modulation (or encoding), and MOK or "M-ary Orthogonal Keying".

A description of these modulations can be found in two general works:

- Andrew J. VITERBI: "CDMA-Principles of Spread Spectrum Communication" Addison-Wesley Wireless Communications Series, 1975,

- John G. PROAKIS: "Digital Communication" McGraw-Hill International Editions, 3rd edition, 1995.

Firstly, phase shift keying modulation is most frequently a binary modulation, referred to as BPSK, or quaternary modulation, referred to as QPSK. In the first case, symbols can be encoded to one bit $m=1$ and, in the second, to two bits $m=2$.

These modulations are generally used in their differential form DBPSK, DQPSK, which ensures satisfactory strength in difficult channels, when no phase retrieval loop is required. This differential form is also very well suited to processing the diversity of propagation paths.

At reception, a differential demodulator performs the multiplication between the signal to be demodulated and its version delayed by a symbol period. In the case of quaternary modulation, two signal channels are used, one channel which processes the component of the signal in phase with a carrier and another channel which processes the component in quadrature with the carrier.

Now, MOK modulation is a technique in which a signal taken from a set of orthogonal signals is associated with each symbol to be transmitted. These signals may be spread codes from the same group of orthogonal codes. In this case, the modulation also carries out the spread. However, these signals may also not be perfectly orthogonal since the orthogonal strain is lower than it seems. Naturally, however, performances are poorer in this case.

If a symbol is composed of m bits, there are 2^m possible configurations for the different symbols. Therefore, the number M of codes available must be at least equal to 2^m . However, if the length of these codes is N , it is known that N orthogonal codes may be found. Therefore, $M=N$ and the number of bits per symbol is limited to $\log_2 N$.

The MOK technique has a variant known as MBOK, M -ary Bi-Orthogonal Keying, consisting of adding, to the set of orthogonal signals used in an MOK modulation, their opposites to form a set of $2M$ signals, which are naturally no longer orthogonal with respect to each other. The demodulation also uses M correlators, adapted to each of the M orthogonal codes, but also requires sign retrieval means.

With the MOK technique, if, to increase the spectral efficiency, the number m of bits in each symbol was increased by one unit, the number M of codes required would be doubled, which would multiply the number of receiver channels by 2. Therefore, the complexity increases at a higher rate than the spectral efficiency. Therefore, this technique involves certain limitations.

MOK and MBOK modulations are used in certain digital communication systems, in conjunction with a coherent reception structure, which requires the knowledge of the phase of the carrier. Sending a preamble, before the transmission of the useful data, is a conventional process enabling the estimation of this phase. However, in channels subject to fading and/or multiple paths, the carrier phase is subject to variations which may be rapid and must be detected and compensated by the reception system. This is generally obtained by the periodic transmission of preambles which then occupy the channel and induce a decrease in the useful data bit rate. According to this scheme, the times of the preamble and the useful data packet must be less than the channel coherence time (time during which the channel is considered to be stationary). In addition, the complexity of the reception structure is increased.

For these reasons, those skilled in the art prefer to use non-coherent, or differentially coherent, demodulation schemes, which do not require the knowledge of the phase data. These techniques do away with the use of long preambles, phase estimators and

phase derotators, in exchange for a slight loss of sensitivity. In addition, non-coherent demodulation simplifies the processing of the diversity of propagation paths very significantly since each path
 5 has, among other things, its own phase (and therefore would require its own phase estimator in a coherent scheme).

The present invention still aims to increase the spectral efficiency of links, while avoiding the
 10 disadvantages mentioned above and making use of the advantages of non-coherent demodulation.

DISCLOSURE OF THE INVENTION

To this end, the invention recommends to multiply
 15 the MOK modulation/demodulation operations to process a plurality of data blocks composed from the data to be transmitted. Naturally, this increases the number of codes, but, as will be seen more clearly below, this also increases the data bit rate very markedly. In the
 20 prior art, doubling, for example, the number of codes increased the number of bits transmitted by only one unit, while, in the invention, doubling the number of codes doubles the bit rate.

Therefore, more specifically, the invention
 25 relates to a data transmission process, characterised in that:

a) at transmission:

- the data to be transmitted is divided into N data blocks,
- 30 - these N blocks are processed in parallel in N M-ary orthogonal keying MOK modulation channels, each

modulation using a group of spread codes, each channel emitting a signal,

- all these signals are transmitted in series.

b) at reception:

5 - the signal received is processed in N M-ary orthogonal keying MOK demodulation channels, giving N data blocks,

- said N data blocks are grouped together in series to reproduce the transmitted data.

10 The MOK modulation and demodulation may consist of conventional type or M-ary bi-orthogonal keying MBOK type modulation and demodulation. They may also consist of an M-ary orthogonal keying modulation/demodulation combined with a phase shift keying PSK modulation/demodulation. The latter may be of the differential type, DPSK.

The number of spread codes may be the same in each group. It may also be different between groups. These numbers may advantageously be to the power of 2.

20 The present invention also relates to a transmitter for the implementation of the transmission phase of this process and a receiver for the implementation of the reception phase.

To underline the multiple nature of the process, 25 and the link with the MOK techniques, the Applicant refers to its technique using the term multi-MOK, or M-MOK for short.

BRIEF DESCRIPTION OF THE FIGURES

30 - Figure 1 is a block diagram of a transmitter according to the invention;

- Figure 2 is a block diagram of a receiver according to the invention;

- Figure 3 is a diagram of a two-channel transmitter using the combined MOK-DPSK technique;

5 - Figure 4 is a diagram of a corresponding receiver;

- Figure 5 is a general diagram of a transmitter with N MOK-PSK type channels;

10 - Figure 6 is a general diagram of a corresponding receiver.

DESCRIPTION OF PARTICULAR EMBODIMENTS

Figure 1 is a schematic representation of a transmitter according to the invention. As shown, it
 15 comprises a main input E receiving the data to be transmitted (generally symbols comprising one or more bits). It is assumed that a packet of this data comprises m bits. This data is divided into N blocks B_1, B_2, \dots, B_N by a serial/parallel converter type
 20 circuit 2. These N blocks comprise m_1, m_2, \dots, m_N bits, respectively; these numbers may be equal, but not necessarily. The transmitter also comprises N MOK modulation means, $4_1, 4_2, \dots, 4_N$. Each of these means
 25 comprises a group of spread codes sufficient in number to process the block it receives. As described in the description of the state of the related art, to process a block of m_i bits, 2^{m_i} codes are required for a
 30 conventional MOK modulation. Since there are N groups of codes, the total number P of codes used in the transmitter is:

$$P = \sum_{i=1}^N 2^{m_i}$$

If all the blocks are composed of the same number of bits, or m_u , and if no code is used several times, the transmitter uses $P = N \cdot 2^{m_u}$ codes and it is capable
 5 of processing $N \times m_u$ bits.

Conversely, given the total number P of codes and the number N of groups, the number m_u of bits per block is:

$$m_u = \log_2(P/N)$$

10 and the total number of bits transmitted is:

$m = \sum_u m_u$, i.e. $N \log_2(P/N)$ if all the blocks have the same number of bits.

It is seen that to multiply the bit rate by N , it is sufficient to multiply the number of codes by N . If
 15 $N=2$, the bit rate is doubled by doubling the number of codes, while in the prior art doubling the number of codes only made it possible to add one bit. Therefore, the gain in terms of bit rate is considerable.

For the transmitter in Figure 1, the means $4_1, 4_2, \dots, 4_N$ emit signals S_1, S_2, \dots, S_N (which are spread codes selected according to the blocks to be
 20 transmitted). These signals are applied to a parallel-serial converter type circuit, the output of which is connected to transmission means 6.

25 Figure 2 represents a corresponding receiver. As shown, this receiver comprises reception means 10, which emit a signal R , which is processed in a group of P filters $11_1, 11_2, \dots, 11_P$ which may be considered to be distributed in N groups of filters, these filters
 30 being adapted to the spread code of the different

groups used at transmission. Each of these filters receives the signal R and emits a filtered signal R_1 , R_2 , ..., R_P .

These filters are followed by the same number of means 12_1 , 12_2 , ..., 12_P to estimate the energy (or amplitude) of the filtered signals and a circuit 13 capable of determining, in each of the N groups of signals, which signal has the greatest energy (or amplitude). The circuit 13 has N outputs S_1 , S_2 , ..., S_N each emitting the rank of the signal with the greatest energy. These outputs are connected to N code tables 14_1 , 14_2 , ..., 14_N which makes it possible to retrieve the N codes corresponding to these N ranks and emit the N corresponding data blocks B_1 , B_2 , ..., B_N . The receiver is completed by a parallel-serial converter type circuit 15, which reproduces, on a main output S, the transmitted data (in m bits).

The present invention may be used within the scope of a particular PSK and MOK technique referred to as DP-MOK. This technique was the subject of the French patent application No. 98 11564 submitted on 16th September 1998 by the present Applicant, but which is not part of the related art to be taken into account for the consideration of the inventive activity of the present invention. In this DP-MOK technique, one part of the bits of each symbol is transmitted according to the MOK technique and another part according to the DPSK technique with spectral spread by the sequence selected for the MOK technique. At reception, the sequence used at transmission is first of all reproduced by adapted parallel filtering, thus

reproducing a part of the bits of the symbol. The appropriate filter signal is demodulated differentially to retrieve the other part of the bits.

Figure 3 shows an embodiment of a transmitter using this DP-MOK technique in the particular case where two channels are used ($N=2$). The two channels comprise the same means indicated by references indexed 1 for the first and 2 for the second. Only the first will be described, since the second can be immediately deduced from it.

The data to be transmitted (m bits) is converted to parallel by a serial-parallel converter 18 which emits two blocks B_1 and B_2 with the same number of bits m_1 and m_2 . The first channel comprises:

- means 22₁ to divide the m bits of B_1 into a first subgroup $(23_{MOK})_1$ of $(m_{MOK})_1$ bits and a second subgroup $(23_{DPSK})_1$ of $(m_{DPSK})_1$ bits where $m_1 = (m_{MOK})_1 + (m_{DPSK})_1$;

- a conversion circuit 28₁ receiving the $(m_{MOK})_1$ bits and converting them to an address directed towards a code table 30₁, which comprises 2 to the power of $(m_{MOK})_1$ orthogonal (or approximately orthogonal) spread codes and finally a generator 32₁ of the selected spread code $(C_i)_1$;

- a differential encoding circuit 24₁, essentially composed of a logic multiplier and a time-delay circuit;

- a PSK modulator referenced 26₁;

- a spectral spread circuit 34₁ working with the code $(C_i)_1$ emitted by the generator 32₁ and applying it to the modulated signal emitted by the modulator 26₁.

The transmitter also comprises a radiofrequency stage 35 connected to the two channels and followed by a transmission antenna.

The corresponding receiver is represented in Figure 4. As shown, it comprises two identical channels, of which only the first will be described. This channel comprises:

- P filters $(40_1)_1, (40_2)_1, \dots, (40_P)_1$ adapted to the P spread codes that can be used at transmission, these filters receiving the signal in the basic band;
- P samplers $(42_1)_1, (42_2)_1, \dots, (42_P)_1$ controlled by a synchronisation signal;
- means 44_1 to determine the filtered signal which has the greatest energy (or amplitude) (maximum squared modulus), these means comprising a first output $(44_1)_1$ carrying the number of the channel corresponding to the maximum signal, and a second output $(44_2)_1$ emitting the actual signal;
- a circuit 46_1 connected to the first output and which, on the basis of the number of the channel corresponding to the signal with the greatest amplitude, emits the data $(m_{MOK})_1$;
- a time-delayed multiplication circuit connected to the second output $(44_2)_1$ and composed of a multiplier 52_1 of a circuit 54_1 inverting the phase and a time-delay circuit 56_1 ;
- a PSK demodulator 58_1 emitting the data $(m_{DPSK})_1$;
- the data $(m_{MOK})_1$ and $(m_{DPSK})_1$ then being grouped together to reconstitute the transmitted symbol S_1 .

The receiver is completed by a parallel-serial converter 60 which groups together the signals S_1 and S_2 and reproduces the m bits transmitted.

The maximum signal selection operation takes some time. As this operation is used to direct one of the inputs to the output (channel switching), it is essential to time-delay the channels by a corresponding time, since the switching must be carried out exactly on the data used for channel selection. Such time-delay operations are standard in such techniques and are not shown.

Figures 3 and 4 are analytical, to give a clearer understanding of this particular embodiment. However, in practice, the circuits may be more synthetic as shown in Figures 5 and 6. These Figures relate to a PSK technique.

Figure 5 shows a transmitter with an input E , a serial/parallel converter 70, a circuit 8 dividing into N MOK blocks and N PSK blocks, a table 90 of P codes receiving on N inputs the N MOK blocks, a circuit 100 receiving the N codes selected in the table 90 and spreading the N PSK blocks, a circuit 110 combining the N spread signals S_1, \dots, S_N , and finally transmission means 112.

Figure 6 shows a receiver with reception means 118, a group of P adapted filters $120_1, \dots, 120_P$, a group of P energy estimation circuits $130_1, \dots, 130_P$ for the filtered signals, a circuit 140 receiving the P estimations and emitting on N outputs the N numbers of the channels carrying the N signals with the greatest energy, N circuits $150_1, \dots, 150_N$ capable of selecting

the channel corresponding to the number addressed to it, N PSK demodulators $152_1, \dots, 152_N$, a formatting circuit 160 receiving on N first inputs N MOK blocks and on N second inputs N PSK blocks, this circuit
 5 emitting, on a main output S , the transmitted data.

Finally, it is possible to calculate the data bit rate obtained according to the invention for some particular cases.

In a first series of examples, it is assumed that
 10 all the codes are different. P is the total number of codes available. For the N codes used simultaneously to be different, at transmission, a code is selected from a group of P/N codes.

The number of MOK bits for each channel is:

15
$$(m_{\text{MOK}})_u = \log_2 P/N$$

$(m_{\text{PSK}})_u$ is the number of PSK bits on each channel.

The number of bits transmitted per symbol is:

$$m = m_{\text{MOK}} + m_{\text{PSK}} = N\{\log_2 P/N + (m_{\text{PSK}})_u\}$$

Table 1 gives some numeric examples of MOK ($N=1$)
 20 (prior art) and M-MOK ($N>1$) (invention where $m_{\text{PSK}}=2$ (QPSK)) modulations.

	$P=8$	$P=16$
$N=1$ (MOK)	$m_{\text{MOK}}=3$ $m=5$ bits/symb	$m_{\text{MOK}}=4$ $m=6$ bits/symb
$N=2$ (M-MOK)	$m_{\text{MOK}}=2$ $m=8$ bits/symb	$m_{\text{MOK}}=3$ $m=10$ bits/symb
$N=4$ (M-MOK)	$m_{\text{MOK}}=1$ $m=12$ bits/symb	$m_{\text{MOK}}=2$ $m=16$ bits/symb
$N=8$ (M-MOK)	---	$m_{\text{MOK}}=1$ $m=24$ bits/symb

In the above examples, it was assumed that all the
 25 codes were different. However, it is possible to reuse

the same code. A special code must then be associated with each code so that the codes transmitted on the channel are always different. Therefore, it is necessary to have P codes plus one special code. For
 5 simplification purposes, the value N=2 is taken.

The channels used are then selected from P and not from P/2. Consequently, the number of transmitted MOK bits is:

$$m_{\text{MOK}} = 2 \cdot \log_2 P \text{ instead of } 2 \cdot (\log_2) - 1$$

10 When the detector detects a data item on the channel of the special code, it knows that the MOK data item is identical on the two channels used.

Numeric examples in the QPSK case:

	P=8,	N=2:	$m = 2(3+2) = 10 \text{ bits/symb}$
15	P=16,	N=2:	$m = 2(4+2) = 12 \text{ bits/symb}$